

11p
163-15562
code - 1

TECHNICAL NOTE

D-1797

MOVING-COCKPIT-SIMULATOR STUDY OF
PILOTED ENTRIES INTO THE EARTH'S ATMOSPHERE FOR A
CAPSULE-TYPE VEHICLE AT PARABOLIC VELOCITY

By John W. Young and Lawrence E. Barker, Jr.

Langley Research Center
Langley Station, Hampton, Va.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON

May 1963

20p

554429

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

TECHNICAL NOTE D-1797

MOVING-COCKPIT-SIMULATOR STUDY OF
PILOTED ENTRIES INTO THE EARTH'S ATMOSPHERE FOR A
CAPSULE-TYPE VEHICLE AT PARABOLIC VELOCITY

By John W. Young and Lawrence E. Barker, Jr.

SUMMARY

15562

A description is presented of a moving-cockpit-simulator study relating to entry guidance for a low-lift-drag-ratio vehicle entering the earth's atmosphere at parabolic velocity. The primary goal of this study was to determine the effect of angular motions on the ability of the pilot to perform the maneuvers required during supercircular entry and to compare the pilot's performance on the moving simulator with that obtained from similar entries on a fixed-base simulator. Consideration was also given to the development of a minimum instrument display for which the pilot used motion cues to aid him in performing the entry maneuvers.

The study established a pilot preference for the moving simulator rather than a fixed-base simulator.

INTRODUCTION

Results of a fixed-base-simulator study (ref. 1) have indicated that the human pilot with experience and an adequate display of flight information can perform the entry guidance maneuvers required to navigate a low-lift-drag-ratio vehicle from parabolic entry to a desired destination. The study of reference 1 was conducted to develop procedures which would allow the pilot to perform the energy-management functions required while avoiding the high-deceleration and skip-out regions associated with parabolic entry and to determine the instrument displays required to aid the pilot in following these procedures.

In the present study a three-axis moving-cockpit simulator was used to produce the angular motions associated with the type of entries investigated in reference 1. The study was conducted to determine the effect of angular motions on the ability of the pilot to perform the maneuvers required during supercircular entries. Whereas the study of reference 1 was somewhat comprehensive and covered procedures for a variety of entry conditions, the present study is limited to a comparison of results obtained for typical entries made on the fixed-base simulator (ref. 1) and on the three-axis moving-cockpit simulator.

DESCRIPTION OF SIMULATION

A six-degree-of-freedom simulation of a space vehicle entering the atmosphere of the earth at parabolic velocity was performed on a three-axis moving-cockpit simulator. A detailed description of the equations of motion, the assumed aerodynamics, and the physical characteristics of the vehicle are given in reference 1.

Description of Vehicle

The simulated vehicle was a capsule type of spacecraft with an offset center of gravity so that the vehicle, when trimmed in the atmosphere at an angle of attack, produced a lift-drag ratio of 0.5. Since the vehicle continuously produced a lift-drag ratio of 0.5, lift modulation was obtained by rolling the vehicle to change the direction of the lift force.

The pilot made use of an on-off reaction control and damping system for regulating the roll angle of the vehicle. Proportional reaction damping systems were used for stabilizing the vehicle in pitch and yaw.

Description of Three-Axis Moving-Cockpit Simulator

The cockpit was mounted on a three-axis gimbal system as shown in figure 1. Pitch-, roll-, and yaw-angle outputs from the analog computer were used to drive the gimbals; this action simulated the angular motions associated with parabolic entry.

The pilot was seated in such a position in the simulator that the roll axis was perpendicular to the midsection of his body and the gravity force always acted in a direction which tended to force him back into his chair. This was accomplished by establishing the convention on the pitch, roll, and yaw gimbals shown in figure 2. In actual practice the simulator could obtain a full 360 degrees of freedom in roll while the pitch and yaw motions were limited to small perturbations ($\pm 5^\circ$) about the trim positions. In this manner the pilot could sense instantaneous changes in pitch and yaw and could feel the true rolling motions while keeping the gravity force always in the same direction. Note that, if the vehicle were allowed to maintain its actual orientation (with respect to inertial axes) during rolling maneuvers, the pilot would be placed in the uncomfortable position of being upside down during many of the maneuvers and as such would be supplied with a means for determining his orientation which would not be available during an actual entry mission.

Instrument Display

The basic trajectory variables displayed on instruments included altitude, velocity, vertical velocity, and deceleration. Also supplied was an attitude group of instruments to show the vehicle's orientation with respect to fixed axes

on earth. In addition, the pilot made use of a navigation instrument which showed errors in the vehicle's position with respect to a stored reference trajectory of range-to-go as a function of altitude and which showed the error in the vehicle's heading with respect to a desired heading that intersected the desired landing area. A complete description of the pilot's instrumentation is given in reference 1. (The memory-scope display described in reference 1 was not used in the present study.)

RESULTS AND DISCUSSION

The results presented in this report are for a limited number of entry conditions and are given primarily for comparison with the fixed-base-simulator results of reference 1. The same test pilots were used in the present study as were used in the study discussed in reference 1. Hence, the pilots were experienced in the operation of the fixed-base simulator.

Comparison of Fixed-Base- and Moving-Simulator Results

for a Typical Entry

Time histories of typical entries performed on a fixed-base simulator and on the moving simulator are given in figure 3. The data given in figure 3(a) were taken from reference 1 and the data in figure 3(b) were obtained for the same entry conditions on the moving simulator. The initial conditions for these entries were an altitude of 400,000 feet, a velocity of 36,000 feet per second, and an entry angle of -6.5° . The desired longitudinal range was 3,500 international nautical miles and the desired lateral range was 300 international nautical miles.¹

The piloting procedure for these entries, as shown in figure 3, consisted of a pull-out at an altitude of about 200,000 feet followed by a coasting phase at this altitude during which the vehicle decelerated to a velocity of about 30,000 feet per second. A pull-up to an altitude of 250,000 feet was then made and the vehicle coasted at this altitude until the reference trajectory was intersected at which time a descent was begun to the desired destination.

As is shown in figures 3(a) and 3(b) there is little difference in the time histories of typical entries on the fixed-base and moving simulators. This agreement was found to be true for all entries studied in the analysis. However, the pilots showed a preference for the moving simulator because they believed that the cues provided by the angular motions of the vehicle aided them in performing the required entry maneuvers. Although the pilots had previous experience in the operation of the fixed-base simulator, it was their general opinion that the training period required to achieve proficiency in the operation of the moving simulator was reduced over that for a fixed-base simulator because of the more realistic physical representation of the assumed vehicle.

¹Altitudes are given in international feet. For conversion to metric units, the following relationship applies: 1 international foot = 0.3048 meter.

Minimum Instrument Display

In reference 1 the effect on range control of removing certain instrument displays was investigated. One conclusion of that study was that, for short range entries in which no pull-up was required, the pilot could navigate to the desired destination by using only the accelerometer, roll-angle meter, and a navigation instrument which showed errors in the vehicle's position and heading with respect to a desired position and heading. An extension to this study was made with the moving simulator. In the present study it was determined that safe entries could be made for which no range control was attempted by using only an accelerometer and an external reference for allowing the pilot to determine the vehicle's orientation in roll. This external reference consisted of a small light source, visible to the pilot through a window in the vehicle. The light source was visible to the pilot only when the vehicle was at or near ($\pm 10^\circ$) a roll angle of zero. A time history for this type of entry is given in figure 4. The piloting procedure used for this entry is given with reference to figure 4.

At the start of the entry (at which time the vehicle was at a roll angle of zero) the pilot noted his orientation with respect to the external reference and maintained this orientation until the deceleration reached a maximum. At this time the pilot rolled the vehicle to direct the lift force downward to prevent the vehicle from skipping out of the earth's atmosphere. This maneuver was made by estimating the time required to roll the vehicle through 180° and by using roll motion cues to stop the vehicle near this orientation. He remained inverted until the deceleration started building up again and then reduced the roll angle to control the deceleration. By looking out the simulator window for the light source to reappear, the pilot could easily bring the vehicle back to a roll angle near zero, as is shown by figure 4. The pilot repeated this procedure throughout the entry (fig. 4) and, as a result, was able to decelerate the vehicle and achieve a safe entry.

The piloting task for this type of entry was found to be relatively simple for an experienced pilot. (The data of figure 4 represented a pilot's first attempt at accomplishing this mission.) This type of entry maneuver might be applicable to an entry mission for which a complete instrument failure had occurred and for which the only concern was in a safe entry into the atmosphere. In an actual entry the heated layer of gas surrounding the vehicle would, of course, preclude use of any external reference except a very bright one such as the sun.

SUMMARY OF RESULTS

The results of a three-axis moving-cockpit-simulator study of piloted entries for a capsule-type vehicle entering the earth's atmosphere at parabolic velocity can be summarized as follows:

1. Although there was no apparent difference in results obtained from the fixed-base simulator and from the moving simulator, the pilots generally believed that the cues provided by the angular motions of the simulator aided them in performing the piloting functions required during entry.

2. Safe entries could be made for which no range control was attempted by using only an accelerometer and an external reference for determining the vehicle's orientation in roll.

Langley Research Center,
National Aeronautics and Space Administration,
Langley Station, Hampton, Va., March 5, 1963.

REFERENCE

1. Young, John W., and Russell, Walter R.: Fixed-Base-Simulator Study of Piloted Entries Into the Earth's Atmosphere for a Capsule-Type Vehicle at Parabolic Velocity. NASA TN D-1479, 1962.

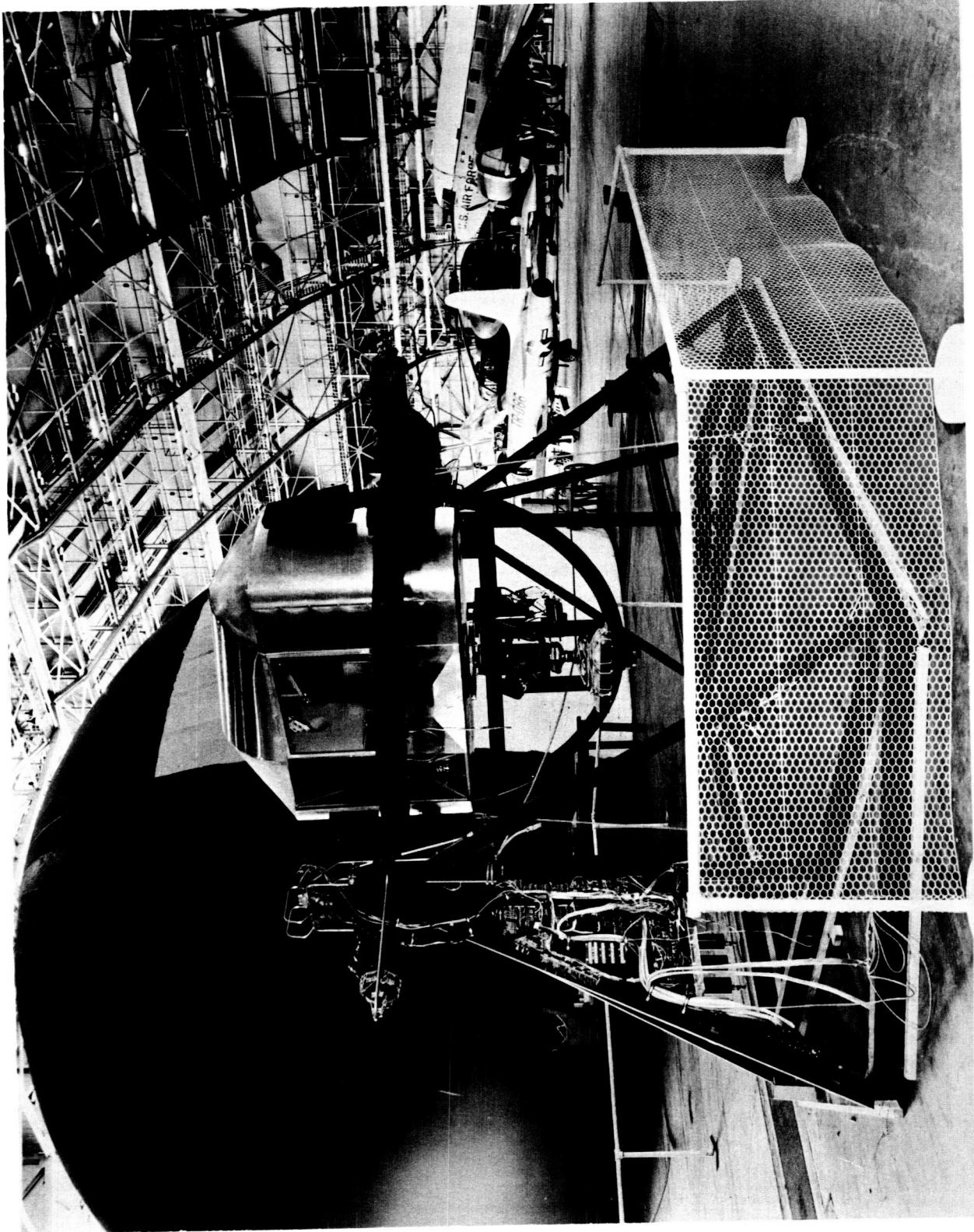
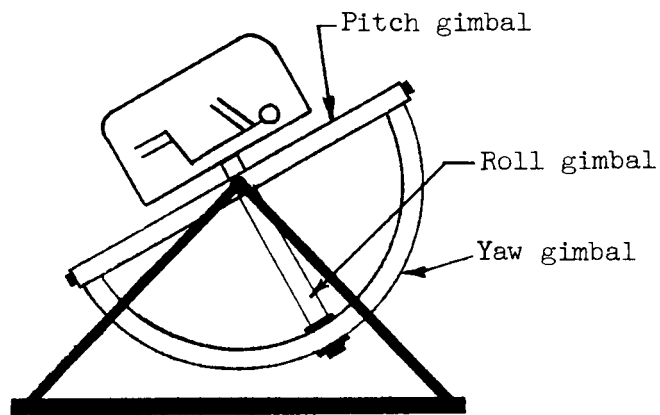
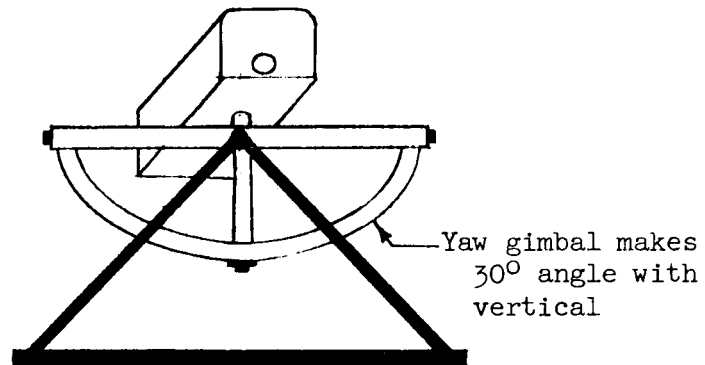


Figure 1.- Layout of three-axis moving-cockpit simulator.

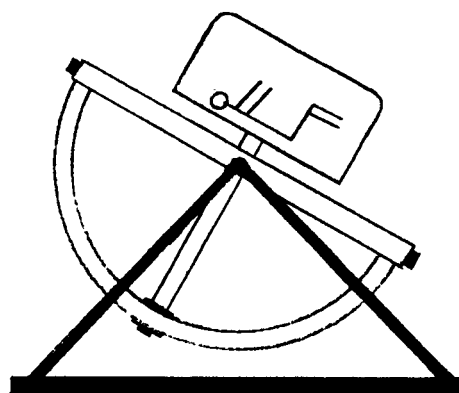
L-62-3361



(a) Roll angle = 0° ; pitch angle = 30° ; yaw angle = 0° .

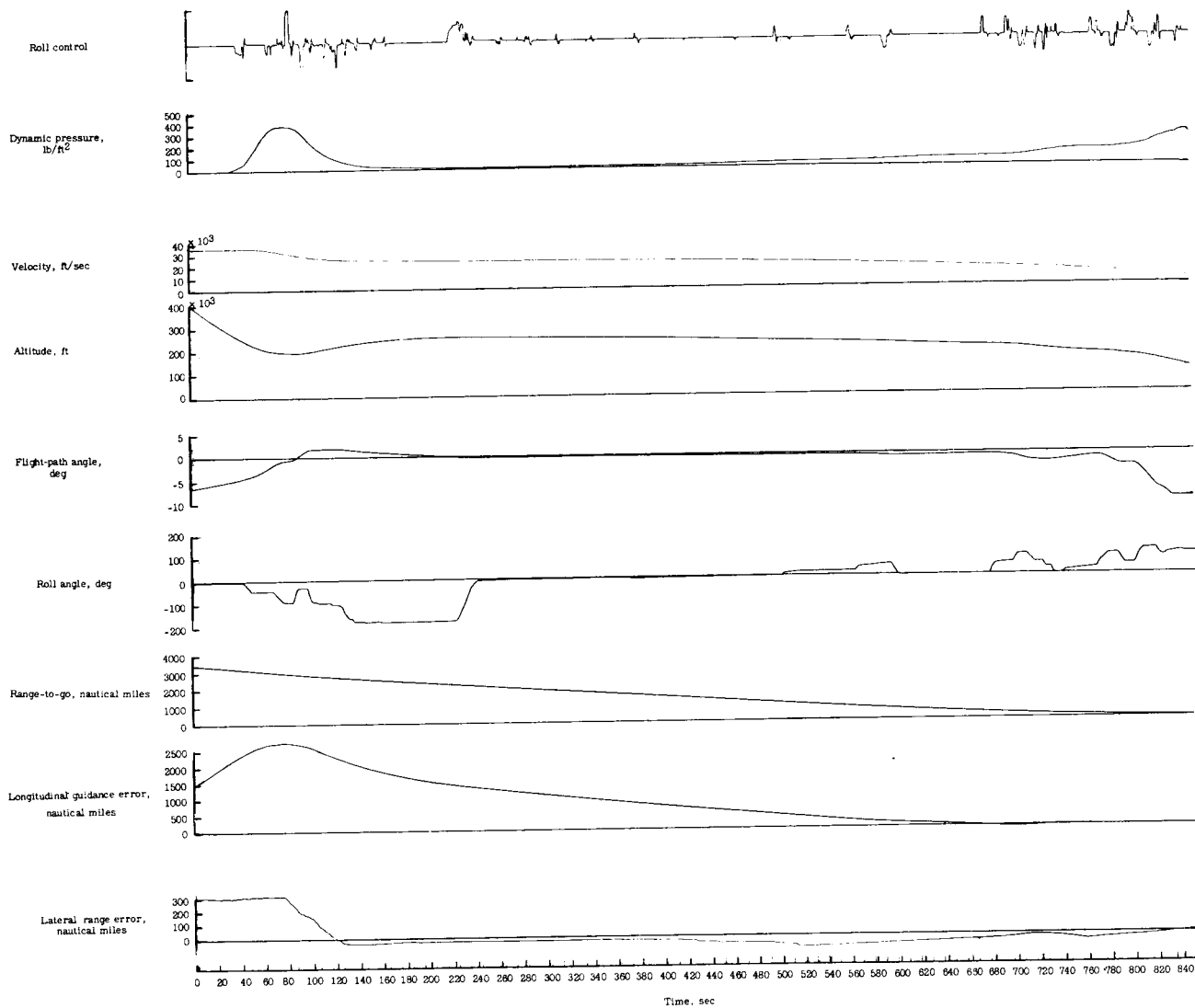


(b) Roll angle = 90° ; pitch angle = 0° ; yaw angle = 30° .



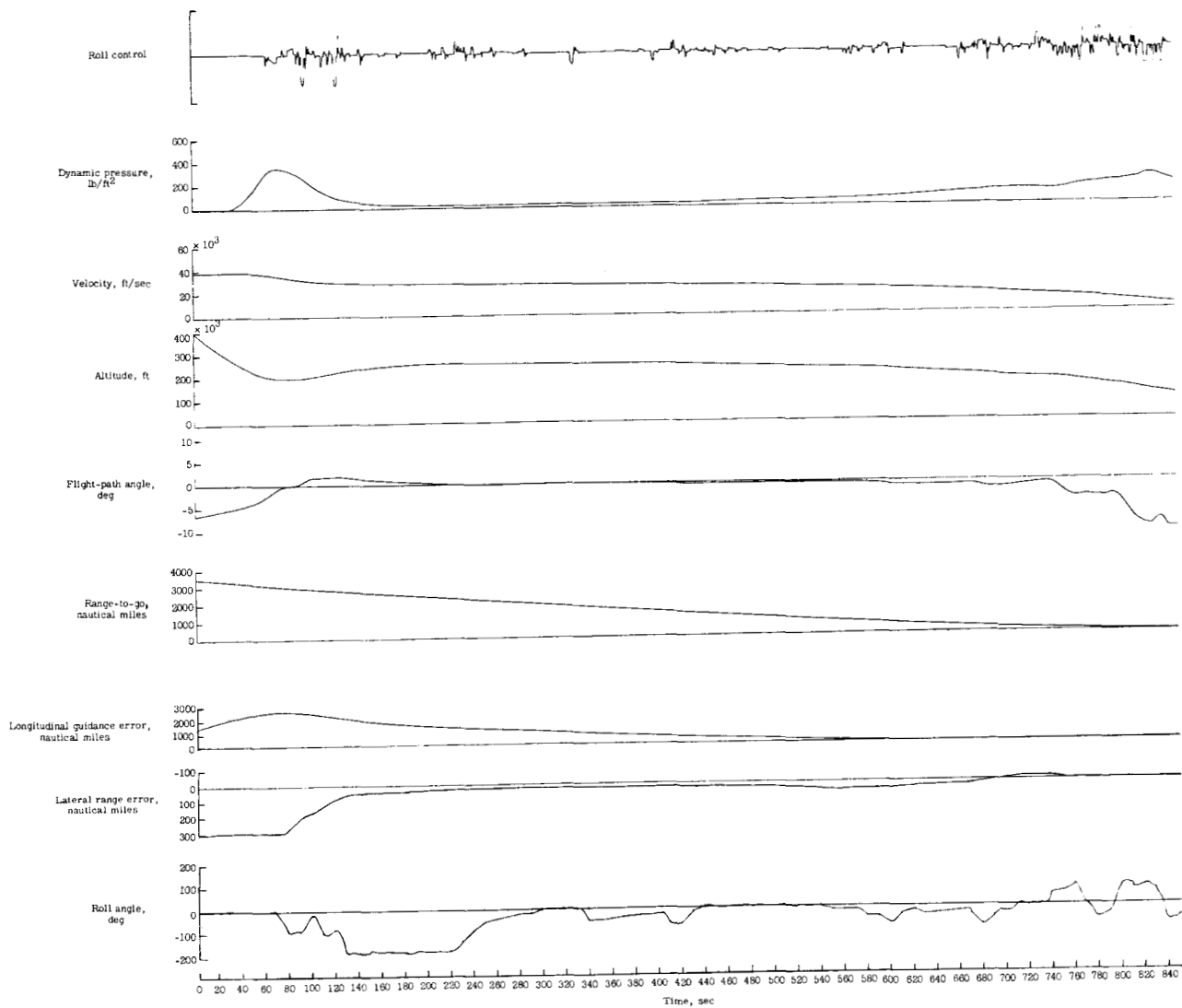
(c) Roll angle = 180° ; pitch angle = -30° ; yaw angle = 0° .

Figure 2.- Gimbal orientation for various roll angles.



(a) Fixed-base simulator (from ref. 1).

Figure 3.- Time histories for typical entries. Initial conditions: altitude, 400,000 feet; velocity, 36,000 feet per second; entry angle, -6.5° .



(b) Moving-cockpit simulator.

Figure 3.- Concluded.

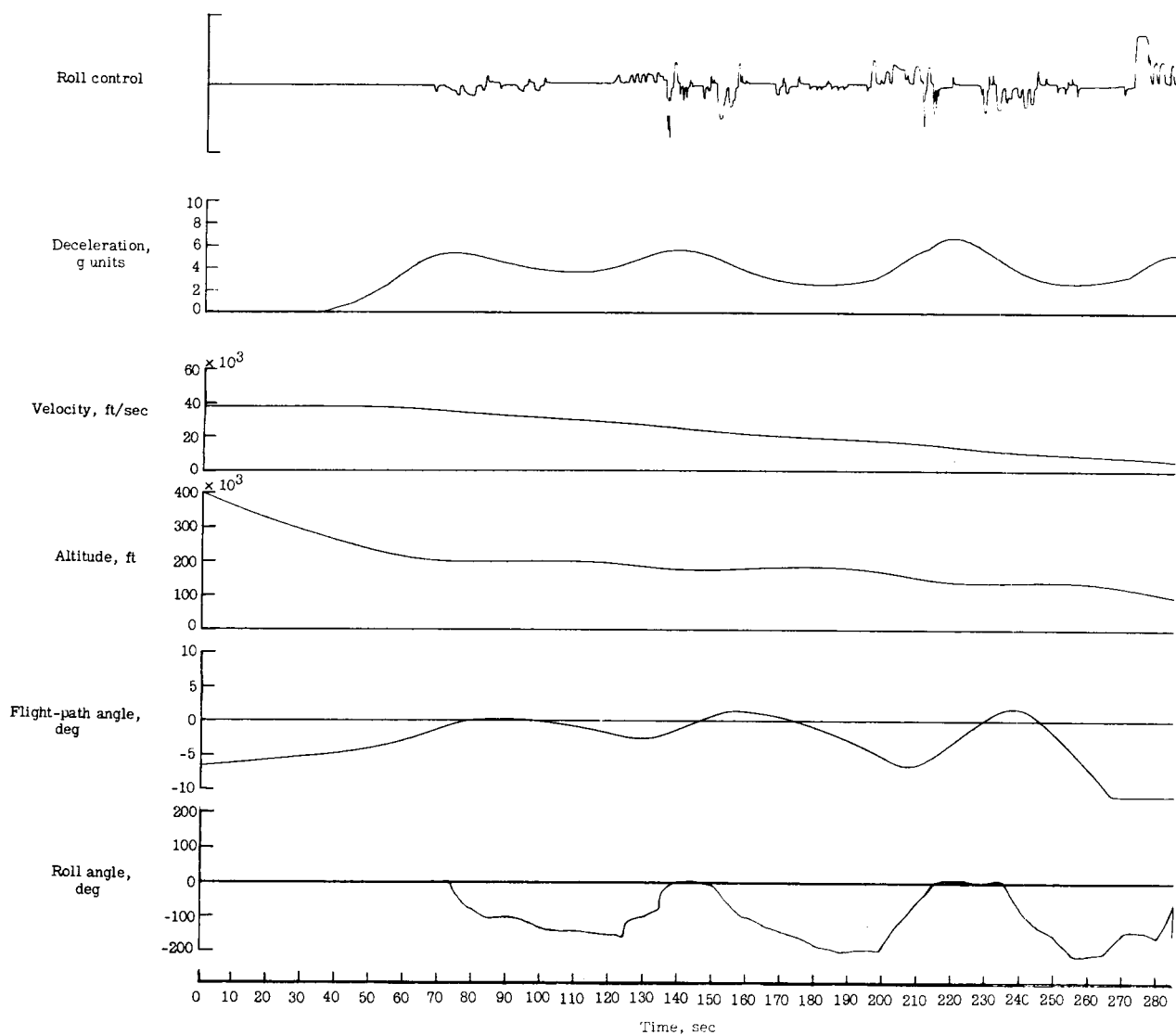


Figure 4.- Time history for entry made with minimum instrument display.